DEPARTMENT OF ENERGY

PRESSURE SEMINAR FOR ENGINEERS

H S - 5 0 6 0

Prepared by

Lawrence Livermore National Laboratory

Updated 9/94

Lawrence Livermore National Laboratory

HS-5060 PRESSURE SEMINAR FOR ENGINEERS
COURSE OUTLINE (6.0 HOURS)

INTRODUCTION & OBJECTIVES . . . . . 15 minutes

ENGINEERING SAFETY NOTES
AND OPERATIONAL SAFETY PROCEDURES . . . . . 30 minutes

AMAGAT/STORED ENERGY . . . . . 30 minutes

~Break~

PRESSURE VESSEL CLOSURES . . . . . 30 minutes

PRESSURE VESSEL DESIGN &
HYDROGEN EMBRITTLEMENT . . . . . 30 minutes

~Break~

PRESSURE VESSEL DESIGN &
HYDROGEN EMBRITTLEMENT (CONT'D) . . . . . 45 minutes

~Break~

PRESSURE TESTING/BARRICADING . . . . . 60 minutes

COURSE EVALUATION, DISCUSSION, AND QUIZ

Pressure Seminar Training Objectives

To provide you with the classroom training that is required to become a reliable and responsible

- [x] **Designer/Checker for (safe design)**
- [x] **User/Supervisor for (safe operation)**

of pressure vessels and systems.

Mechanical Engineering Department Certified Welding

P R O C E D U R E N 0. 3-7

TO: **Mechanical Engineering Department Personnel**

SUBJECT: **Certified Welding in Mechanical Shops**

The Mechanical Shops Division will provide certified welders for jobs where certification is called out on the drawing. Such jobs should be drawn to the attention of the Mechanical Shops Division metallurgist or welding engineer as early in the design phase as possible.

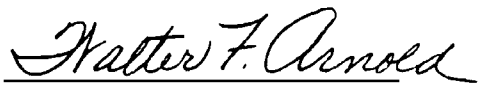
The metallurgist or welting engineer will establish a specific procedure for certifying a welder for each job. The welder to be certified will be given detailed instructions for each step in the procedure. He must then perform satisfactory welds on samples that have been specially prepared by the Shops for this specific procedure. These sample welds will be subjected to mechanical or nondestructive tests and metallurgical examination. If these tests are satisfactory, the welder will be given any additional precautions deemed necessary in applying the same procedure to the actual job. He will then be considered to be certified for that job.

Documentation will be prepared by the Shops to certify that the job was done in accordance with the procedure. It will include a sign-off check sheet.

It must be emphasized that this procedure assures that the weld has been done in accordance with recorded procedures by a certified welder. It does not produce a certified weld. The weld itself can be certified only by successfully conducting the proof tests and/or nondestructive tests specified by the engineer responsible for the design.

Since welder certification is expensive and time consuming, it should only be specified for critical applications where high reliability is essential such as high pressure hydrogen containers, radioactive material containers, fabrications intended to meet State and Federal pressure codes (Particularly for off-site use) or structures in which failure would present a hazard to life or limb.

As the Shops build up a file of procedures, it is expected that many routine jobs can be performed by calling on these.



Walter F. Arnold

WFA:ol

UW-12 Joint Efficiencies

(a) all Category A and B welds connecting vessel sections or heads shall be of Type No. (1) or Type No. (2) of Table UW- 12;

(b) any Category B and C butt welds (but not including Category B and C butt welds in nozzles and communicating chambers that neither exceed 10 in. nominal pipe size nor l l/8 in. wall thickness) which are not required to be fully radiographed by subparagraphs (1), (2), (3), or (4) above shall, as a minimum requirement, be partially radiographed. This shall consist of a radiographic examination at least 6 in. long of any section of the weld picked at random, plus a similar examination of any intersections of the weld with all Category A welds in either of the sections being connected. Acceptance standards for partially examined welds shall be as set forth in UW-51 for full radiography.

(6) all butt welds joined by electroslag welding;

(7) ultrasonic examination in accordance with UW-53 may be substituted for radiography for the final closure seam of a pressure vessel if the construction of the vessel does not permit interpretable radiographs in accordance with Code requirements. The absence of suitable radiographic equipment shall not be justification for such substitution.

(b) Spot Radiography. Butt welded joints made in accordance with Type No. (1) or No. (2) of Table UW-12 which are not required to be fully radiographed by (a) shall be examined by spot radiographing in accordance with UW-52, except as described in (c). Spot radiographic examination is not required of Categories B and C butt welds in nozzles and communicating chambers that neither exceed 10 in. nominal pipe size nor l l/8 in. wall thickness.

NOTE: This requirement specifies spot radiography for butt welds of Type No. (1) or No. (2) that are used in a vessel, but does not preclude the use of fillet and/or corner welds permitted by other paragraphs, such as for nozzle and manhole attachments, welded stays, flat heads, etc., which need not be spot radiographed.

(c) No Radiography. Except as required in (a), no radiographic examination of welded joints is required when the vessel or vessel part is designed for external pressure only, or when the vessel design complies with UW-12(c).

(d) Electroslag welds in ferritic materials shall be ultrasonically examined throughout their entire length in accordance with the requirements of appendix 12. This ultrasonic examination shall be done following the grain refining (austenitizing) heat treatment or postweld heat treatment.

(e) In addition to the requirements in (a) and (b), all welds made by the electron beam process shall be ultrasonically examined for their entire length in accordance with the requirements of appendix 12.

UW-12 JOINT EFFICIENCIES

Table UW-12 gives the joint efficiencies *E* to be used in the formulas of this Division for joints completed by an arc or gas welding process. The joint efficiencies depend on the type of joint and on the degree of examination of the joints.

(a) The value of E not greater than that given in column (a) of Table UW-12 shall be used in the design calculations for fully radiographed butt welds [see UW-I l(a)].

(b) The value of *E* not greater than that given in column (b) of Table UW-l 2 shall be used in the design calculations for butt welded joints in vessels or parts of vessels that are spot-radiographically examined in accordance with the requirements of UW-11(b), and for longitudinal stress calculations when partial radiography is used under UW-11(a)(5).

Seamless vessel sections and heads with Category B, C, or D butt joints that are spot radiographed in accordance with UW-11(b) shall be designed for circumferential stress using a stress value equal to 85% of the allowable stress value prescribed for the material in Subsection C (this stress reduction is not applicable to t_r and t_{rn} in reinforcement calculations).

(c) The value of *E* not greater than that given in column (c) of Table UW-12 shall be used in the design calculations for welded joints in vessels that are neither fully radiographed nor spot-radiographically examined, provided that in all other design calculations a stress value equal to 80% of the allowable stress value prescribed for the material in Subsection C is used except for stress S for unstayed flat heads and covers in UG-34, stresses S_a, S_b, S_f, and S_n used in flange design and defined in 2-3, for calculating the thickness of braced and stayed surfaces by Eqs. (1) and (2) of UG-47(a), or for stresses S_m and S_b used in design of noncircular vessels as applied in appendix 13.

(d) A value of E not greater than 0.80 may be used in the formulas of this Division for joints completed by any of the pressure welding processes given in UW-27(b), except for electric resistance welding, provided the welding process used is permitted by the rules in the applicable parts of Subsection C for the material being welded. The quality of such welds used in vessels or parts of vessels shall be proved as follows: Test specimens shall be representative of the production.

Table UW-12 maximum allowable joint efficiencies for arc and gas welded joints

Table UW-12
MAXIMUM ALLOWABLE JOINT EFFICIENCIES FOR ARC AND GAS WELDED JOINTS

No.	Type of Joint Description	Limitations	Degree of Examination (a) Fully Radio-graphed[1]	(b) Spot Examined[2]	(c) Not Spot Examined[3]
(1)	Butt joints as attained by double-welding or by other means which will obtain the same quality of deposited weld metal on the inside and outside weld surfaces to agree with the requirements of UW-35. Welds using metal backing strips which remain in place are excluded.	None	1.0	0.85	0.70
(2)	Single-weld butt joint with backing strip other than those included under (1)	(a) None except as in (b) below. (b) Butt weld with one plate off-set–for circumferential joints only, see UW-13(c) and Fig. UW-13.1 sketch (k).	0.90	0.80	0.65
(3)	Single-welded butt joint without use of backing strip.	Circumferential joints only, not over 3/8 in. thick and not over 24 in. outside diameter.	---	---	0.60
(4)	Double full fillet lap joint.	Longitudinal joints not over 3/8 in. thick. Circumferential joints not over 5/8 in. thick.	---	---	0.55
(5)	Single full fillet lap joints	(a) Circumferential joints[4] for attachment of heads not over 24 in. outside diameter to shells not over 1/2 in. thick. (b) Circumferential joints for the attachment to shells of jackets not over 5/8 in. in nominal thickness where the distance from the center of the plug weld to the edge of the plate is not less than 1 1/2 times the diameter of the hole for the plug.	---	---	0.50
(6)	Single full fillet lap joints without plug welds	(a) For the attachment of heads convex to pressure to shells not over 5/8 in. required thickness. Only with use of fillet weld on inside of shell; or (b) for attachment of heads having pressure on either side to shells not over 24 in. inside diameter an not over 1/4 in. required thickness with fillet weld on outside of head flange only.	---	---	0.45

NOTES:
(1) See UW-12(a) and UW-51
(2) See UW-12(b) and UW-52.
(3) The max. allowable joint efficiencies shown in this column are the weld joint efficiencies times 0.80 (rounded off to the nearest 0.05), to effect the basic reduction in allowable stress required by this Division for welded vessels that are not spot examined. See UW-12(c).
(4) Joints attaching hemispherical heads to shells are excluded.

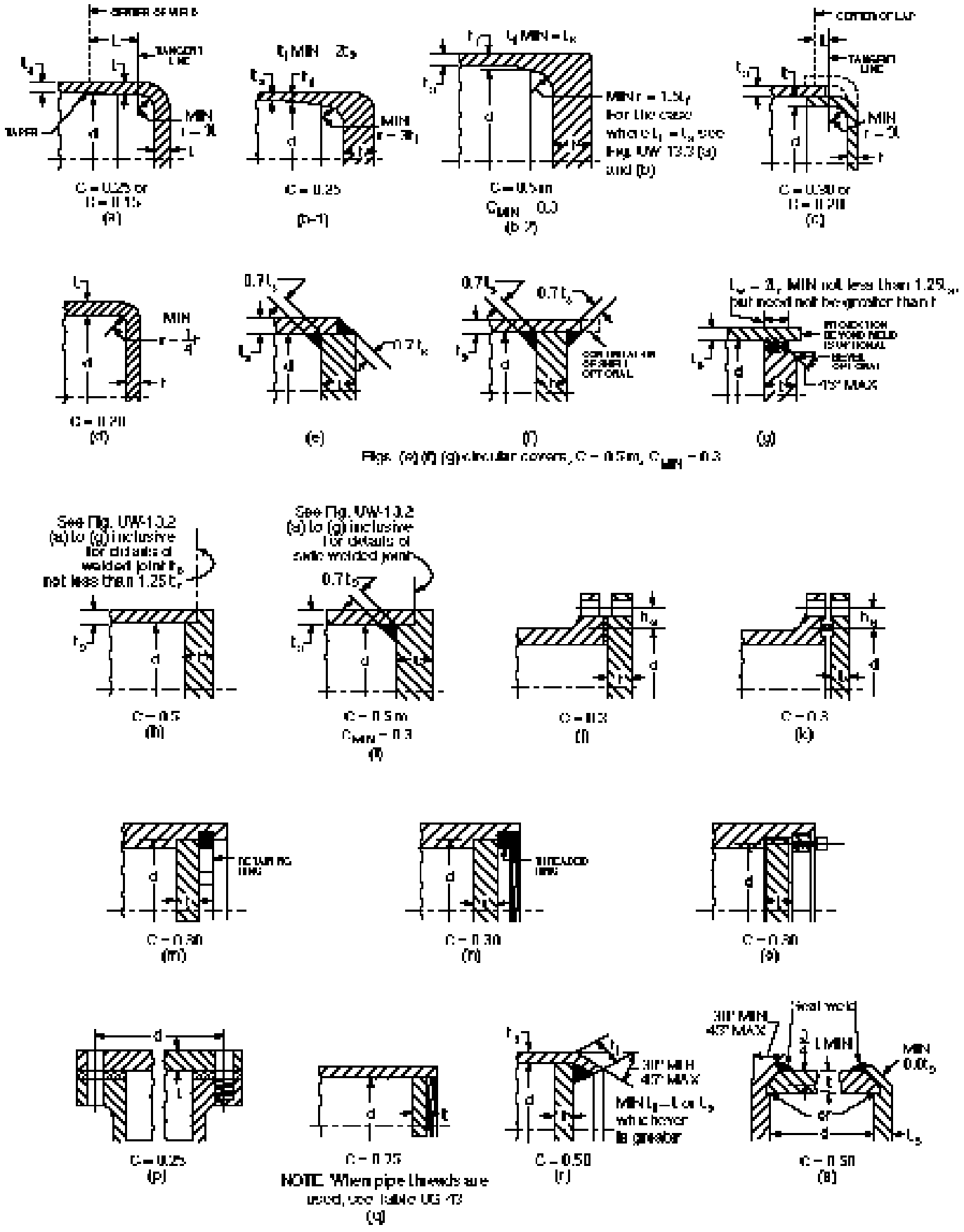


FIG. UG-34. SOME ACCEPTABLE TYPES OF UNSTAYED FLAT HEADS AND COVERS
The above illustrations are diagrammatic only. Other designs that meet the requirements of UG-34 are acceptable.

Appendix A

Outline
Generic Engineering Safety Note
For A Pressure System

February 16, 1990

By

David C. Holten

FORWARD

A large portion of pressure hardware/systems, requiring engineering safety notes at LLNL, are relatively standard and straight-forward in design and use. Our experience at the Building 343 High Pressure Laboratory is that such systems are regularly either ignored or at the other extreme, over analyzed. This note has been prepared to provide a more stream-lined, less painful alternative in documenting such designs. It, however, is not all encompassing; it does not address all possible safety/design integrity issues. Individual authors must enlarge and embellish applicable content as dictated by the complexity of the design. Please reference LLNL Health and Safety Manual, Chapter 32 and Supplements 32-03, 32-05. With such cautions, this generic skeleton is offered, hopefully as a more standard, straight-forward form of engineering documentation for these types of pressure systems.

Recommended Distribution:

Applicable management/supervision

Pressure Consultant

Industrial Safety Representative

Pressure Safety Representative

Responsible Designer

Central Library/Files

(others concerned, including Building Coordinator)

Appendix A, continued

(900 Series Division
Engineering Note Number)

MECHANICAL ENGINEERING SAFETY NOTE

_____
(Title)

_____
(Date)

By

_____
(Author)

Prepared by	_____ Responsible Individual	_____ Date
Reviewed by	_____ Pressure Consultant	_____ Date
Reviewed by*	_____ (DIVISION) Reviewer	_____ Date
Approved by	_____ (DIVISION) Division Leader	_____ Date

*OPTIONAL

A. DESCRIPTION

This Engineering Safety Note covers (**brief description**). It is approximately (**volume/dimensions**) in size and weighs about (**weight**). The intended use of this (**system name**) is (**describe use so reader has clear understanding of what's involved, i.e., function, working fluid, etc.**). It will be (**manned area/remotely**) operated. It is located in and will be (**fixed or mobile**) from that location. The MAWP and MOP for this is _____ psig and _____ psig respectively. It (**is/is not ASME and/or DOT**) rated. Attached as page is _____ (**drawing number or sketch**) describing this _____ will be _____ _____ .
(**Document number**) describes the operating procedure for this _____ (if applicable).

B. HAZARDS

(**Perform this calculation for a gas system**)

This system represents a potential hazard to personnel and equipment by virtue of the stored energy available in a sudden isentropic depressurization. The major source of stored energy in this _____ is (**largest volume @ MAWP**).

The energy equivalent of a pressurized gas source, assuming a reversible adiabatic (isentropic) expansion is given by

$$E = \frac{P_1 V_1}{K-1}\left[1-\left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}}\right]$$

Equation (11) Pg. 20, Ref. 1

Where

P_1 = _____ psia
P_2 = Atmospheric Pressure
V_1 = Volume of the vessel
K = C_p/C_v = Ratio of specific heats
E = Stored energy

Appendix A, continued

For this design

P_1 = _____ psia

P_2 = 14.7 psia

V_1 = _____ cc

K = _____ (**gas used**)

Adjusting the above equation for the proper units and substituting values gives:

$$E(\text{gmsTNT}) = 1.492 \times 10^{-6}\left[\frac{p_1(\text{psi})V_1(\text{cc})}{K-1}\right]\left[1-\left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}}\right]$$

= 1.492 x 10^{-6} [ ] [ ]

E = _____ gms TNT

(For liquid systems, perform stored energy calculations based on compressibility information for the specific fluid, i.e., for water, reference page 6-10, Marks Handbook, 9th Edition, or END 88-039.)

Additional hazards in the use of this _____ are (**toxic, radioactive, loss of power, operation above MAWP, material compatibility, etc. Why are these hazards acceptable, i.e. - hoods, barricades, protective clothing, special procedures, etc.? Reference related OSP's**).

C. CALCULATIONS

(Commercially procured)

This _____ (**is made completely of/or contains**) commercial high pressure components. All have pressure ratings equal to or exceeding the manned area use for which they will be used. A listing of these items follows:

Component	Manufacturer	Part Number	Rated Pressure

For these items, no calculations are required.

(Design/Built in-house)

This _____ contains elements that are (**inhouse designed/built/modified)**. To insure safe operation at MAWP, a calculational analysis of these features is provided.

1. Features analyzed should include:

   • Hoop stress
   • End closures
   • Bolt-thread shear and tensile cross-sections
   • Stresses in welds
   • Stresses in other critical features
   • Analysis of shields/barricades

2. Provide basis for safety factors used. State exact reference location for all equations and material properties used.

3. For critical vendor designed components, i.e. - vessels, intensifiers, etc., -- reference and if applicable, attach any manufacturer's analysis pertaining to the component.

4. For systems containing low yield strength materials, i.e. - 300 series SST, a distortion energy analysis should be included in this paragraph, to insure no yielding at test

D. PRESSURE TESTING

Initial: All pressure testing is to be done at ambient temperature and shall use _____ as the testing fluid. Pressure tests shall be performed at _____ psi which is _____ times MAWP. Pressure shall be held for _____ minutes minimum. Leak criteria during this test shall be (**method of leak detection, leak rate, etc., if applicable**).

*Following pressure testing, this _____ shall be leak tested at _____ psi, which is 1.0 times MAWP. Leak criteria for this test shall be (**method of leak detection, allowable leak rate, etc.**) .

All pressure tests shall be performed by an LLNL High Pressure Technician and witnessed by an LLNL Pressure Inspector.

***If required.**

(To insure no yielding of critically stressed components, dimensional measurements should be specified before and after testing, for example, a principle diameter at three different locations).

(For a system containing several pressure operating zones, pressure test values should be specified for each zone).

Prior to pressure testing, all relief devices and gauging rated below test pressure must be removed from the system, and replaced with an appropriate plug. (**For systems containing gages and pressure reliefs**).

RETEST/REINSPECTION

This system requires a re-inspection every three (3) years and a retest every 6 years. These shall be performed by an LLNL High Pressure Technician and witnessed by an LLNL Pressure Inspector. Re-testing shall be done at _____ psi which is 1.0 times MAWP.

Appendix A, continued

E. LABELING

The Pressure Inspector will certify the inspection of this _____ by completion of an LLNL Pressure Test inspection Record, Form LL3586, and by attaching an LLNL PRESSURE TESTED label, filled out as follows:

LLNL PRESSURE TESTED
FOR MANNED AREA

ASSY.
SAFETY NOTE
M.A.W.P **PSIG.**
FLUID
TEMP. **TO** **°F**
REMARKS
TEST NO. **T.R.**
EXPIRATION DATE
BY **DATE**

F. ASSOCIATED PROCEDURES

(List all procedures and documents cited in the body of this ESN).

G REFERENCES

1. LLNL Health and Safety Manual, Supplement 32-03, August, 1987 revision .

(List all references cited in the body of this ESN)

Appendix B

MECHANICAL ENGINEERING SAFETY NOTE

Safety Manifold for 6,000 psi Gas Test Connections

Sept. 5, 1990

Prepared by: _____ _____
Jay Brentjes 3-2746 Date
High Pressure Lab

Reviewed by: _____ _____
Dave Holten Date
NEED Pressure Consultant

Approved by: _____ _____
Allan Copeland Date
NEED Division Leader

Distribution:
C. Borzileri
Bldg. 343 Personnel
Engineering Info Center
HPL Library

Appendix B, continued

A DESCRIPTION:

This Engineering Safety Note covers two types of safety manifolds commonly used with 6,000 psi gas cylinders. These manifolds are primarily intended for controlling and measuring a wide range of gas pressures of small systems or pressure vessels. For example, HPL personnel can use these manifolds for conducting pressure tests in the field. They can be used with inert gases or nitrogen. The MAWP of the system is 6,000 psi; however, the pressure gauge and pressure relief device may be selected for any value up to the 6,000 psi to provide the pressure range and maximum limit for the particular test or system. The manifolds are shown in Figures 1 and 2. Since there will be more than one manifold of this type, each unit conforming to this Safety Note will be serialized.

B. HAZARDS:

The stored energy of pressurized gas represents the only hazard to personnel in case of a sudden depressurization or rupture. The volume of gas contained inside the manifold components is very small, normally less than five cubic inches. At 6,000 psi this represents a stored energy of 5,100 foot pounds or an equivalent of 1.5 grams of TNT (ref. END 90-009 for formulas). All components except the pressure gauge and relief device are rated for pressures in excess of 6,000 psi as indicated in Figures 1 and 2. The pressure gauge and relief device need to be selected as a compatible set:

1) The relief device should be set to approximately 120% of the intended delivery pressure.
2) The full scale value of the pressure gauge should be 1.3 to 2 times the setting of the relief device.
3) The pressure relief device shall be set, verified and tagged in accordance with reference 3.

C. PRESSURE TESTING AND LABELING:

Pressure testing of this manifold shall be done with nitrogen or inert gas at ambient temperaturc. The relief dcvice and pressure gauge shall be removed and the port(s) closed with an appropriate cap or plug. For the initial test, the system is pressurized to 1.25 times the MAWP or 7500 psi inside one of the HPL test cells and held at pressure for five to ten minutes. The pressure is then reduced to 6,000 psi or lower and the system is checked for leaks using a sniffer probe and leak detector or other appropriate device. This pressure test is to be performed by an LLNL Pressure Technician and witnessed by an LLNL Pressure Inspector. After successful completion of the test, the Pressure Inspector prepares and affixes a "LLNL PRESSURE TESTED" label to the manifold. He also prepares a record form LL3586 and forwards this to the LLNL Pressure Safety Manager. The manifold shall be inspected once every three years and retested once every six years at the MAWP by a Pressure Inspector.

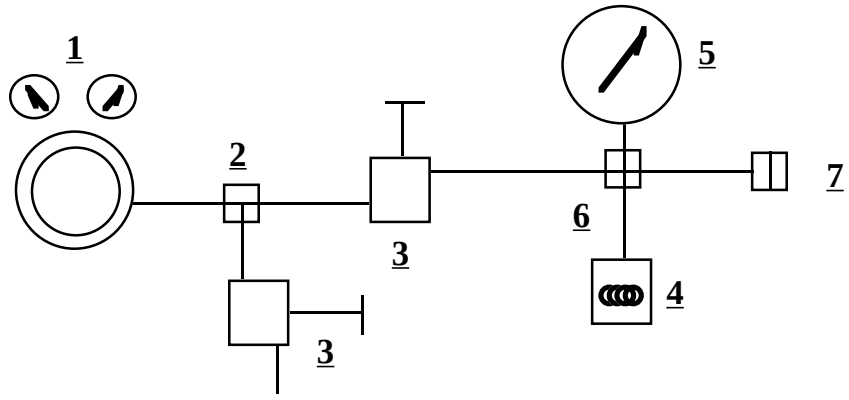
D. REFERENCES:

1. LLNL Health and Safety Manual, Supplement 32-03.

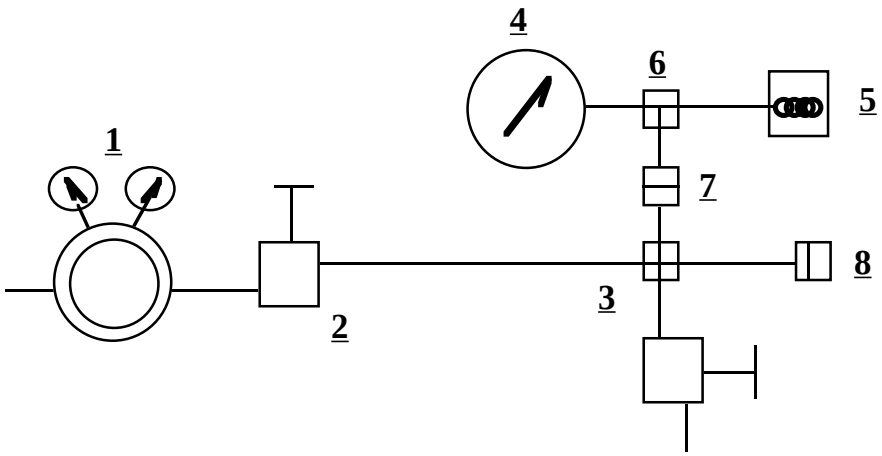
2. END 90-009, "Outline Generic Engineering Safety Note for a Pressure System," Dave Holten, Feb.16,1990.

3. END 90-026, "Pressure Relief Device Setting and Verification Procedures in Use at the Lawrence Livermore National Laboratory," Jay Brentjes, August, 1990.

Appendix B, continued



1. Regulator, Mateson 3066S-677, 0-10,000 psi
2. Street Tee, Cajon SS-4-ST, 6,900 psi
3. Valve, Autoclave Eng. 10A-1013-4, 10,000 psi
4. Relief Valve (setting depends on test pressure)
5. Pressure Gauge (range depends on test pressure)
6. Cross, Cajon SS-4-CS, 6,900 psi
7. Adapter, Autoclave Eng. 6M44N3, >10,000 psi
8. Misc. Pipe Fittings, Cajon SS Nipples, 7,500 psi



1. Regulator, Mateson 3066S-677, 0-10,000 psi
2. Valve, Autoclave Eng. 10A-1013-4, 10,000 psi
3. Cross, Cajon SS-4-CS, 6,900 psi
4. Pressure Gauge (range depends on test pressure)
5. Relief Valve (setting depends on test pressure)
6. Tee, cajon SS-4-T, 6,900 psi
7. Adapter, Autoclave Eng. 6M44N3, >10,000 psi
8. Misc. Pipe Fittings, Cajon SS Nipples, 7,500 psi